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Global CO_2-Trade and Local Externalities

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Abstract

The burning of fossil fuels not only causes CO_2 emissions but at the same time impairs local environmental quality such as ambient air quality. The present paper analyzes the possible distortion arising from international trade in CO_2 emissions when local externalities persist. It is theoretically derived that the maximal possible distortion is determined by the difference in factor endowment and population density of the trading regions. Moreover, an empirical illustration for Switzerland shows that a rich country buying emission rights sustains a welfare loss.

Keywords: International CO_2 policy, emission trading, second-best analysis

JEL classification: D62, H21, Q40

[•] I am indebted to Michael Kosfeld and Urs Fischbacher for many helpful comments.

1 Introduction

Among economists there is a strong belief that international trade of CO_2 emission rights lowers the cost of attaining a predetermined global emission level. Accordingly, the Kyoto Protocol assigns emission rights to various countries and at the same time allows for the possibility of emission trading. Although the modalities of this trading scheme are still to be negotiated, Grubb notes in his economic appraisal of the Protocol that ”... the most striking feature of the Kyoto Protocol is the degree of flexibility ... particularly in comparison with previous agreements”[1].

While the efficiency gain of trade is theoretically undisputed, it is also beyond controversy that the theory applies to a first best world. In a second best situation, however, trade is not necessarily welfare-improving. In this paper it is argued that, with respect to international carbon trade, a serious second best problem exists. The problem arises because the burning of fossil fuels not only produces CO_2 emissions but at the same time causes a series of local environmental problems such as air pollution. In Switzerland, for example, it is estimated that between 2,500 and 4,600 people die prematurely due to air pollution caused by the burning of fossil fuels and that the total cost amount to around five percent of GDP. If these local effects are not internalized, international trade in emission rights will proceed at prices that do not reflect the true local cost of fossil fuel use. As a consequence, an international trading scheme for CO_2 emissions does not render an efficient international allocation of fossil fuels.

The joint production of global and local environmental effects when fossil fuels are burned is hardly mentioned in the literature. Cline (1992) notes that the spillover of carbon policy on local air pollution is important; however, he does not elaborate on it[2]. Boyd, Krutilla and Viscusi (1995), another exception, compute the welfare effects of carbon policy in the U.S. taking into account the local environmental impacts. They conclude that these local effects reduce the cost of carbon policy considerably. Their analysis, however, does not include international carbon trade.

Besides that, there is a great deal of literature on international carbon policy as well as on the environmental impact of international trade. Yet, neither of these research branches explicitly considers the joint production aspect of fossil fuel burning. In Dornbusch and Poterba (1991) as well as in OECD (1991) and Siebert (2000), various economic, political and technical

[1] Grubb (2000), p.4.
[2] Cline (1992), p. 128.

aspects of the global warming problem are analyzed, but local environmental effects are not addressed. In its special edition on the cost of the Kyoto Protocol, the Energy Journal presents a multitude of models calculating the welfare gain resulting from international carbon trade[3], again, without taking account of local environmental impacts.

The consequences of international commodity trade on the environment have been analyzed extensively. Siebert (1977) showed that countries with a relatively low valuation of environmental quality have a comparative advantage in the production of pollution-intensive goods. Copeland and Taylor (1994, 1995) theoretically deduce that such a reallocation of pollution-intensive production increases world pollution if the global distribution of income is highly unequal. Perroni and Wigle (1994) calculate these effects with a CGEM considering both global and local environmental deterioration. In their analysis, a move to free trade only leads to a slight reduction in environmental quality. The result implies that the nexus between commodity trade and environmental quality is not very tight and, as a consequence, that the second-best problem arising from commodity trade is not substantial. With respect to international carbon trade, however, such a conclusion cannot be drawn. Since the burning of fossil fuels is considered to be one of the main causes of local environmental problems in most countries, international carbon trade affects national environmental quality considerably. Therefore, a welfare analysis of international carbon trade should take into account local environmental effects as long as they are not internalized.

This paper analyzes the second-best problem arising from international trade in globally restricted carbon emission rights when local externalities persist. It attempts to isolate the forces determining the possible distortion arising from international carbon trade. As it turns out, differentials of income and population density between trading regions are of major relevance. The larger these differentials are the bigger is the possible distortion of carbon trade. This result is politically crucial since it is expected that, once a carbon trading scheme is established, rich countries will purchase emission rights from poorer countries.

The remainder of the paper proceeds as follows. Section 2 introduces a simple model of a trading region and deduces energy demand as a function of prices. Section 3 compares the international equilibrium of two trading regions with the second-best solution and discusses the efficiency loss due to international carbon trade. Section 4 empirically illustrates the analysis in the case of Switzerland. It computes the welfare loss the country induces when it buys carbon emission rights. Finally, section 5 concludes the paper.

[3] Weyant and Hill (1999)

2 The demand for energy

The model in Table 1 describes the economy of a trading region. Since it is assumed that the model applies to all regions equally, no regional sub-indices are used at this stage of the analysis.

Table 1: The model of a trading region

Utility function	$U = U(c,Q)$	(I.1)
Production function	$Y = Y(Nl^Y, E)$	(I.2)
Local environmental quality	$Q = Q(\frac{Nl^Q}{S}, \frac{E}{S})$	(I.3)
Trade balance	$Nc = Y - \overline{P}_E E - P_R\left(E - \overline{R}\right)$	(I.4)
Non-tradable factor market	$N\left(l^Y + l^Q\right) = N\bar{l}$	(I.5)

Notation:

c : individual consumption of private good

Q : local environmental quality

Y : internationally traded macro output

N : population size

l^Y : individual non-tradable factor input into production of Y

E : energy input into production of Y

l^Q : individual non-tradable factor input into production of Q

S : regional surface

$\overline{P}_E$: given world market price of physical energy

P_R : endogenous price of CO_2 emission right

$\overline{R}$: endowment of CO_2 emission right

$\bar{l}$: individual supply of non-tradable factor

The utility of a representative individual is determined by consumption of a private commodity c and the public good Q, which depicts regional environmental quality. Since the welfare analysis below compares states at an exogenously given world energy use, global environmental quality is also fixed and, therefore, can be ignored.

Two production factors, a non-tradable factor and fossil energy, produce the private good Y at constant returns to scale. In equation (I.2), l^Y specifies the individual and Nl^Y the total allocation of the non-tradable factor to the production of the macro-output. E, on the other hand, describes the amount of energy used by the entire region.

Local environmental quality Q is understood as environmental quality on site, such as the concentration of air pollutants per volume. Therefore, the production of local environmental quality includes a spatial dimension. Environmental quality is dependent on energy input per surface and on the non-tradable factor per area allocated to abatement activities. With such a formulation, it is guaranteed that scaling up a region leaves ambient environmental quality unaltered. Furthermore, for the results derived below, it is sufficient to assume that the first derivative of Q is positive with respect to the input of the non-tradable factor and negative with respect to energy input. Also, we assume the population size N to be so large that the individual ignores the effects of his activities on Q.

The private commodity, which serves as numéraire, and energy are traded internationally, giving rise to the trade balance (I.4). Note that the total price of energy comprises two parts, the price of fossil energy itself $\overline{P}_E$ and the price of the emission right P_R. To simplify the model, it is presumed that the price of energy itself is exogenous and that the regions trading emission rights have no endowment of energy themselves. Such an assumption implies that a third region, such as the group of oil exporting countries, offers energy at a given price. The price of the emission right, on the other hand, is endogenous and the trading partners are assigned a given amount of emission rights $\overline{R}$. Finally, the non-tradable factor endowment is exogenous and can be allocated to the production of the private commodity or the public good respectively (I.5).

In the economy described in table 1, energy affects utility via two channels. The positive effect works through the production of the private good. The negative impact results from the deterioration of the public good, which causes a negative externality.

We now derive the demand for energy in two settings. In the first setting, energy demand follows from private optimization, and in the second setting from social optimization. With private optimization, the individual considers environmental quality as given, since the effects of his decisions on environmental quality are external. Thus, utility maximization reduces to the maximization of private consumption c:

$$\max_E U = U\left(c,\overline{Q}\right), \tag{1}$$

$$\text{where: } c = \frac{Y - \overline{P}_E E - P_R\left(E - \overline{R}\right)}{N}.$$

In the private setting, there is no incentive to undertake abatement activities , and therefore $l^Q = 0$ and $l^Y = \bar{l}$. To maximize utility, we set the derivative of c with respect to E to zero, and derive the simple result that the composite energy price equals the private marginal product of energy[4], i.e.:

[4] The second order condition for a maximum is fulfilled by the assumption of a decreasing marginal product of energy.

$$\frac{\partial Y}{\partial E} = \overline{P}_E + P_R . \qquad (2)$$

The energy demand in (2) arises from private maximization in a situation without policy interference. However, with social optimization, the effect of energy input on the public good must be taken into account. In this case, utility is maximized with respect to both, private consumption and environmental quality. Moreover, the allocation of the non-tradable factor is now part of the optimization problem:

$$\max_{E,l^Y} U = U(c,Q). \qquad (3)$$

The derivative with respect to E then yields:

$$\frac{\partial U}{\partial c}\left(\frac{\partial c}{\partial Y}\frac{\partial Y}{\partial E} + \frac{\partial c}{\partial E}\right) + \frac{\partial U}{\partial Q}\frac{\partial Q}{\partial E}. \qquad (4)$$

From the trade balance, we know that $\frac{\partial c}{\partial Y} = \frac{1}{N}$ and $\frac{\partial c}{\partial E} = -\frac{\overline{P}_E + P_R}{N}$. Substituting these results and the derivative of the environmental quality function into (4), we arrive at the implicit energy demand[5]:

$$\frac{\partial Y}{\partial E} + \frac{\partial U/\partial Q}{\partial U/\partial c}\frac{\partial Q}{\partial (E/S)}\frac{N}{S} = \overline{P}_E + P_R \qquad (5)$$

With social optimization, the energy price $\overline{P}_E + P_R$ equals the social marginal product of energy, which comprises the private and the public marginal product. The public marginal product (the second term on the l.h.s. of (5)) corresponds to the value of the externality[6]. The internalization of the externality with a Pigouvian tax guarantees that private maximization leads to the social optimum. In this case, the individual would balance the private marginal product of energy and the price of energy which includes the externality.

The value of the externality increases with population because more people are affected by ambient pollution, and it decreases with area size because an additional unit of energy use is dispersed across a greater area and, therefore, causes less pollution on site.

Taking the derivative of (3) with respect to l^Y, considering that $\partial l^Q = -\partial l^Y$, yields the optimal allocation of the non-tradable factor:

$$\frac{\partial U/\partial C}{\partial U/\partial Q} = -\frac{\partial Q/\partial\left(N l^Y/S\right)}{\partial Y/\partial\left(N l^Y\right)}\frac{N}{S}. \qquad (6)$$

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[5] To meet the second order condition, we need to assume that environmental quality is a normal good and that marginal damage of energy use is not decreasing.

Equation (6) constitutes a slightly modified Samuelson rule for the optimal allocation of a public good. The marginal rate of substitution between the private and the public good equals the marginal rate of transformation multiplied by population density. Again, population size determines the number of people affected by a change in environmental quality, and the area size specifies the amount of abatement activities of the non-tradable factor per area.
From the implicit demand functions (2) and (5) respectively we now deduce the price of the emission right when two regions trade a globally restricted amount of emissions.

3 Comparison of the trade equilibrium with the second best optimum

In order to derive the trade equilibrium of two regions, labeled A and B, we distinguish two cases. In the first case, no region internalizes its local environmental externalities; in the second case, one region internalizes and the other does not. The situation in which both regions internalize their external effects is not analyzed, because the second best problem does not arise and carbon trade is efficient.

3.1 No region internalizes

When both regions trade energy without taking account of local environmental effects, the equilibrium allocation of globally restricted energy equalizes the private marginal product of energy in the two regions, i.e.:

$$\frac{\partial Y}{\partial E}\left(\overline{N}_A \bar{l}_A, E_A\right) = \frac{\partial Y}{\partial E}\left(\overline{N}_B \bar{l}_B, E_B\right), \tag{7}$$

with: $E_A + E_B = \overline{R}_A + \overline{R}_B \equiv \overline{E}$.

Note again that, without internalizing environmental pollution, the non-tradable factor is fully allocated to the production of the private good.
Figure 1 illustrates the analysis, depicting private and social marginal valuation as a function of energy in both regions. Energy use is mapped starting from the left for region A and from the right for region B. The trade equilibrium, then, is achieved at the intersection of the energy

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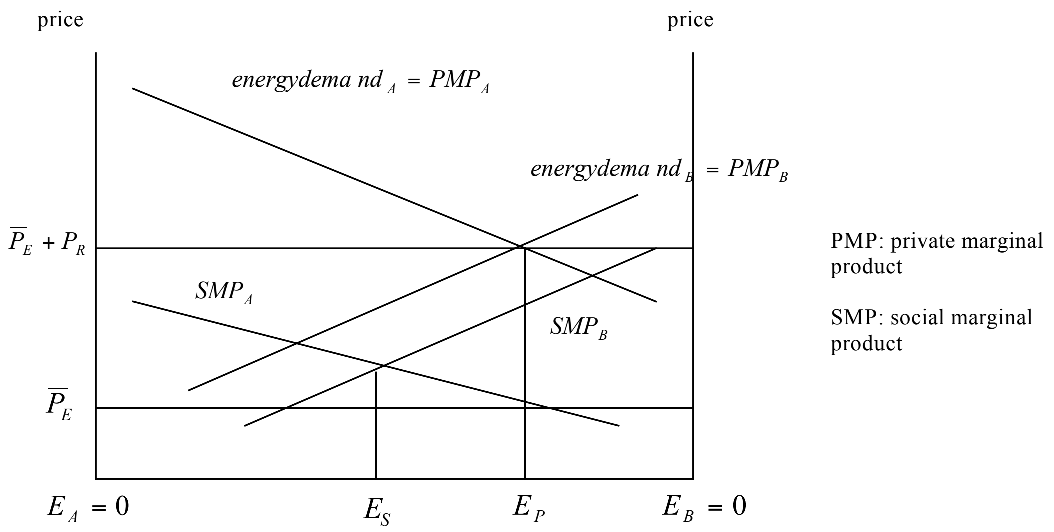
[6] Note that the value is negative because $\frac{\partial Q}{\partial (E/S)} < 0$.

demand curves E_P, while the second-best solution is located at the intersection of the social marginal product curves E_S.

Figure 1: Private equilibrium and second-best optimum when no region internalizes



When discussing the relative position of E_P and E_S, it is first noted that if the two regions differ by a scale effect only, the social value of energy is equal in both regions. In this case, the trade equilibrium constitutes a second-best solution because population density is equal in both regions, and, therefore, consumption per capita c, energy use per area E/S as well as environmental quality Q are also equal.

However, due to the second-best problem, the trade equilibrium as described by equation (7) generally does not equalize the social marginal products in the two regions, which correspond to

$$\frac{\partial Y}{\partial E}\left(\overline{N}_A\bar{l}_A, E_A\right) + \frac{\frac{\partial U}{\partial Q}\left(c_A, Q_A\right)}{\frac{\partial U}{\partial c}\left(c_A, Q_A\right)} \frac{\partial Q}{\partial (E/S)}\left(0, E_A/\overline{S}_A\right)\frac{\overline{N}_A}{\overline{S}_A} \tag{8}$$

in region A, and to

$$\frac{\partial Y}{\partial E}\left(\overline{N}_B\bar{l}_B, E_B\right) + \frac{\frac{\partial U}{\partial Q}\left(c_B, Q_B\right)}{\frac{\partial U}{\partial c}\left(c_B, Q_B\right)} \frac{\partial Q}{\partial (E/S)}\left(0, E_B/\overline{S}_B\right)\frac{\overline{N}_B}{\overline{S}_B} \tag{9}$$

in region B.

In the following, we concentrate on two criteria that distinguish the regions and, thus, give rise to different social valuation of energy: factor endowment and population density[7].

Factor endowment

The wealth of a region is determined by the endowment of the non-tradable factor as well as by the assigned amount of emission rights. However, for any plausible case, the endowment of the non-tradable factor crucially determines the relative wealth position. Given the emission prices assumed below, the value of the emission right is only in the range of a few percent of GDP. Therefore, we will focus on different endowments of the non-tradable factor. However, in order to derive clear-cut results, we start by setting the emission rights proportional to the total amount of the non-tradable factor (NL). Such an assignment takes account of the region's previous emission. Due to its political feasibility, 'grandfathering' is a commonly used distribution key in the existing trading schemes of environmental policy[8].

If population density in A and B is the same but region A is richer in the sense that $\overline{L}_A = k\overline{L}_B$ ($k > 1$), then the assumption of constant returns to scale in the production of the private good yields $E_A = kE_B$ and $Y_A = kY_B$ at the private optimum. Under the prerequisite that $\overline{R}_A = k\overline{R}_B$, the ratio of per capita consumption also equals k, which is shown in equation (10):

$$c_A = \frac{Y_A - \overline{P}_E E_A - P_R\left(E_A - \overline{R}_A\right)}{N} = \frac{kY_B - k\overline{P}_E E_B - kP_R\left(E_B - \overline{R}_B\right)}{N} = kc_B . \tag{10}$$

While private consumption is larger in the richer region, environmental quality is lower due to the higher energy input per area. Hence, with environment quality being a normal good[9], its marginal value is also higher. Moreover, with $\partial^2 Q / \partial E^2 \leq 0$, the marginal deterioration of the environment in the rich region is not smaller than in the poor country. Therefore, at the trade equilibrium, the value of the externality is larger and the social marginal product of energy is smaller in the rich country. The second-best optimum in figure 1 must lie on the left side of the trade solution[10].

Note that the specifically assumed distribution of emission rights exactly corresponds to the trade equilibrium. Because such a distribution would not generate any emission trading, the introduction of trade would not cause any additional distortion. However, with any other

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[7] Possible differences in the production and environmental quality functions are not considered. As long as we do not know how these functions differ, an empirical application of such theoretical results is not feasible.

[8] See, e.g., Keohane et al (1997) or Hahn (1989).

[9] On the superiority of environmental quality see, e.g., Braden and Kolstad (1991).

[10] A sufficient condition for the value of the externality in A being higher is that $\overline{R}_A \geq \overline{R}_B$. However, considering the small share of R in total wealth, the above condition is far from necessary.

initial assignment of emission rights, trade might impair the international allocation of energy. The maximal possible distortion arises if the initial distribution is at the second-best optimum. The more unequal the valuation of the externality, the higher the distortion. The value differential, in turn, rises with the wealth difference between the trading partners.

Population density

Next we analyze the case where the regions differ in population density but have the same individual endowment of the non-tradable factor. In this instance, the more densely populated area employs more energy per area, which yields lower environmental quality. With initial emission rights proportional to population[11], per capita consumption is equal in both regions. The value of the externality, however, is higher in the more densely populated area because the public good is scarcer relative to the private good and more people are affected by pollution. Again, with emission rights assigned according to previous emissions, the trade equilibrium is foreclosed and no trade will occur. With any other endowment of emission rights, the implementation of trade can lead to increased distortion. Proposition 1 summarizes these considerations.

Proposition 1: Assume constant returns to scale in the production of the private good, non-decreasing marginal damage of energy, and environmental quality being a normal good. Then the maximal possible distortion arising from international carbon trade when no trading region internalizes its local externalities increases with differences in individual wealth and population density.

Factor endowment versus population density

In order to examine if population density or personal wealth has a stronger impact on the value of the externality, we analyze the special case where one region (A) is richer and the other (B) is more densely peopled. Total factor endowment per area, however, is set equal, i.e. $\overline{N}_A \bar{l}_A / \overline{S}_A = \overline{N}_B \bar{l}_B / \overline{S}_B$. Furthermore, the endowment of emission rights is assumed to be the same in both areas. In this case, energy input, production of the private good and environmental quality is also equalized. However, per capita consumption is higher in A and, therefore, the public good is more scarce. In B, on the other hand, more people are exposed to pollution. To compare the two countervailing effects more precisely, it is needed to introduce

[11] Since the endowment of the non-tradable factor is equal in both regions, such a distribution of emission rights is also proportional to total factor endowment Nl.

a specific utility function. To illustrate, we choose a Cobb-Douglas utility. Equation (11) shows that with such a utility function the ratio of the marginal rate of substitution between the two countries equals the ratio of per capita consumption. But since the inverse of this ratio corresponds to the relative density of the two regions, the two effects exactly offset each other.

$$
\begin{aligned}
&\frac{\frac{\partial U}{\partial Q}(c_A,Q_A)}{\frac{\partial U}{\partial c}(c_A,Q_A)}\frac{\partial Q}{\partial(E/S)}\left(0,E_A/\overline{S}_A\right)\frac{\overline{N}_A}{\overline{S}_A}=\frac{\frac{\partial U}{\partial Q}(kc_B,Q_B)}{\frac{\partial U}{\partial c}(kc_B,Q_B)}\frac{\partial Q}{\partial(E/S)}\left(0,E_B/\overline{S}_B\right)\frac{\overline{N}_B}{k\overline{S}_B}\\
&=k\frac{\frac{\partial U}{\partial Q}(c_B,Q_B)}{\frac{\partial U}{\partial c}(c_B,Q_B)}\frac{\partial Q}{\partial(E/S)}\left(0,E_B/\overline{S}_B\right)\frac{\overline{N}_B}{k\overline{S}_B}=\frac{\frac{\partial U}{\partial Q}(c_B,Q_B)}{\frac{\partial U}{\partial c}(c_B,Q_B)}\frac{\partial Q}{\partial(E/S)}\left(0,E_B/\overline{S}_B\right)\frac{\overline{N}_B}{\overline{S}_B}
\end{aligned}
\tag{11}
$$

In order to illustrate the theoretical analysis numerically, we adopt the regional classification of the Population Reference Bureau[12], which divides the world into a more developed and a less developed region. In this data set, the per capita income of the developed region is fifteen times higher, while the less developed area is two and a half times more densely populated. Hence, total non-tradable factor endowment per area NL/S is around six times higher in the rich region. From equation (11), it can be derived that the more developed countries value local externalities higher then the less developed. Although, in the rich region, two and a half times fewer people are affected by pollution, they value it around fifteen times higher than in the poor region. Therefore, in comparison to the second-best solution, too much energy is allocated to the rich region. A reallocation of fossil fuels to the poor countries would enhance overall efficiency. The incidence of such a shift, however, would be for the benefit of the rich and at the cost of the poor.

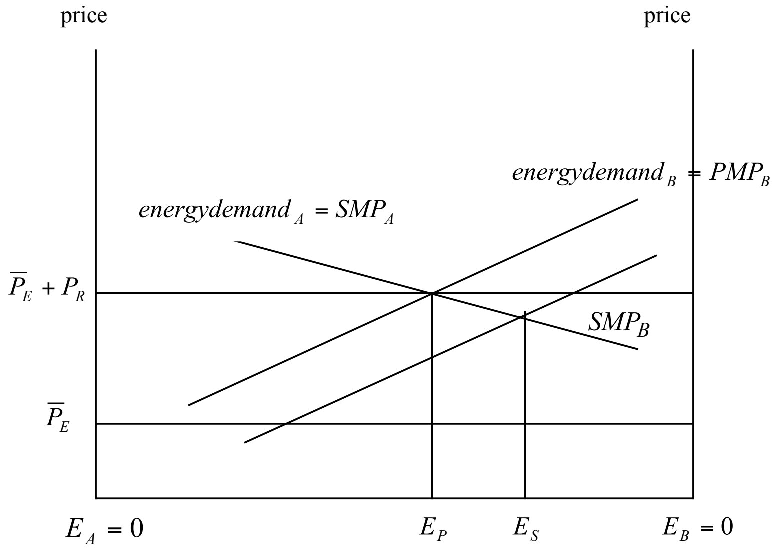
3.2 One region internalizes

Since the environmental quality function Q includes abatement, an internalization generally leads to a reallocation of the non-tradable factor to the production of the public environmental good. Such a shift of the non-tradable factor leads to a cleaner use of energy and, therefore, reduces the – negative – marginal public product of energy $\partial Q/\partial(E/S)$. The private marginal product of energy $\partial Y/\partial E$, however, is also reduced, because less of the non-tradable factor is employed. With a set of plausible assumptions, it can be shown that the social marginal

[12] www.prb.org/pubs/wpds2000/wpds2000_GNP-capital.html

product of energy increases when external effects are internalized[13]. In this case, the SMP function of the internalizing region shifts upwards. The size of the upward shift depends on the productivity of the non-tradable factor in the production of a cleaner environment.

Figure 2: Private equilibrium and second-best optimum when one region internalizes



In any case and independent of the exact value of the marginal social product, an internalization of local externalities yields an energy demand that corresponds to its social marginal product. Figure 2 shows this situation when region A internalizes. The trade equilibrium now results at the intersection of the social marginal product of region A and the private marginal product of region B. The second-best optimum E_S lies on the right of the trade equilibrium E_P. The distance between E_S and E_P is determined by the value of the externality in the non-internalizing region. From above, we know that the value of the externality depends on individual factor endowment and population density. Proposition 2 can then be stated as follows.

Proposition 2: The maximal possible distortion arising from international carbon trade when one trading region internalizes its local externalities increases with individual wealth and population density in the non-internalizing region.

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[13] Namely, the provisions are that the production and environmental quality function are multiplicatively separable in the factors E and l, that the marginal product of energy in Y is not increasing and that the marginal damage of energy in Q is not decreasing. For the possibility of a corner solution, i.e. no abatement activities, see Selden and Song (1995) on the J-curve of abatement.

If the non-internalizing region is both poor and sparsely populated, the pollution externality is valued low and, as a consequence, the trade equilibrium is close to the second-best solution. If utility were quasi homothetic in the sense that, at low income levels, environmental quality does not affect utility, the externality might vanish. In this case, the second-best solution would correspond to the trade equilibrium.

Up to now, we discussed the maximal possible distortion of carbon trade which emerged if the initial assignment of emission rights corresponded to the second-best optimum. The actual distortion, however, can only be derived, if the actual endowment of emission rights is known. In the next section, we derive numerical results by applying the theory to Switzerland.

4 Empirical illustration for Switzerland

The theory above suggests that environmental quality is lower in rich countries that do not internalize local pollution. This is due to the higher usage of energy in production. However, if the rich countries internalize external effects, abatement activities are initiated and environmental quality rises. If the abatement effect is strong enough, environmental quality in the rich countries rises beyond the level in the poor countries.

With a cross-county panel, Grossman and Krueger (1995) as well as Selden and Song (1994) show that there is a fairly stable relationship between per capita income and local pollution, which is described as the environmental Kuznets curve. At low income levels, local pollution increases with rising income. However, there is a turning point at around 8,000 dollars (1985 price level). From this level on, higher income is related to less pollution. Grossman and Krueger explain this empirical finding with a high income elasticity of environmental demand. With greater prosperity, higher demand for the public good triggers a political process which leads to stricter environmental regulations[14].

Such a development can also be observed in Switzerland. Since the enforcement of the federal environmental law in 1983, the emission of air pollutants such as nitrogenoxids, sulphuroxids or volatile organic compounds has been reduced considerably. However, it is important to note that, despite these measures, the burning of fossil fuels still causes local environmental effects that are not fully reflected by the energy price. Thus, the private demand curve lies above social valuation of energy and the quantity demanded is too high.

Table 2: Prices, tax rates and externalities of fossil energy sources (in Swiss francs per units customary in trade[15])

	Gasoline CHF/liter	Diesel CHF/liter	Heating oil CHF/100 liter	Natural gas 0.01 CHF/kWh
Gross price (private marg. product)	1.40	1.40	46	4.19
Existing tax rate	0.85	0.88	4	0.31
Net price	0.55	0.53	42	3.88
Marginal externality				
Minimum	0.74	0.56	32	2.12
Maximum	0.175	1.90	87	5.89
Social marginal product				
Minimum	-0.19	-0.03	10	1.76
Maximum	-1.20	-1.37	-45	-2.01

Table 2 presents prices, existing tax rates and the marginal externality of the four fossil energy sources gasoline, diesel, heating oil and natural gas respectively. It shows that the existing tax on gasoline and diesel is substantial, amounting to 60 percent of the gross price. However, even with respect to these fuels, the remaining externality is still so high that the resulting social marginal valuation is negative. The value of the external effects (row 4 and 5 in table 2) is calculated on the basis of a series of studies that were commissioned by the Swiss government.[16]. To take account of the various uncertainties of external cost estimates, we work with a lower and upper bound. To give an example, an additional unit of gasoline bought at the given price caused an efficiency loss between 0.19 and 1.20 CHF. In other words, the efficient price of gasoline that internalized all local externalities lies between 2.14 and 3.15 CHF.

With a CGEM of Switzerland, Felder and Schleiniger (1999) calculate that the internalization of these local externalities would reduce total carbon emissions by 30 to 50 percent[17]. This means that, down to this level, Switzerland could reduce its carbon emissions at no cost. However, in its federal law on the reduction of CO_2 emissions, the country only committed to reduce its emissions by 10 percent with respect to the 1990 level[18]. The carbon tax rate needed to attain such a ten percent reduction can be derived from the Swiss general equilibrium

[14] Grossman and Krueger (1995), p. 372.
[15] 1 Swiss franc corresponds to 0.6 dollars (February 2001).
[16] For a more detailed discussion of these cost estimates, see Felder and Schleiniger (1999). Note that these costs include only local external effects. Effects on the global climate are not taken into account.
[17] Felder and Schleiniger (1999), p.11.

model. With implicit price elasticities of demand ranging between 0.1 and 0.76 for the various energy sources, the carbon tax rate amounts to 166 Swiss francs per ton of carbon which corresponds roughly to 100 dollars. Such a tax raises the price of gasoline by approximately 10 percent.

In order to determine if Switzerland would buy or sell emission rights if international carbon trade is introduced, the global price of emission rights must be known. Weyant and Hill (1999) give a comprehensive overview on various models, all trying to calculate the economic consequences of complying with the Kyoto targets. If global carbon trade is permitted, estimates of the carbon tax rate range between 25 and 125 dollars per ton of carbon[19]. Since these calculations refer to the year 2010, the tax range must be reduced substantially to be comparable to the Swiss tax rate of 100 dollars, which corresponds to the present situation. Given these numbers, it seems most probable that Switzerland would buy emission rights on an international market. As a consequence, Swiss energy usage as well as local pollution would increase compared to a situation without international carbon trade.

Figure 3: Swiss surplus of international carbon trade as a function of global emission price

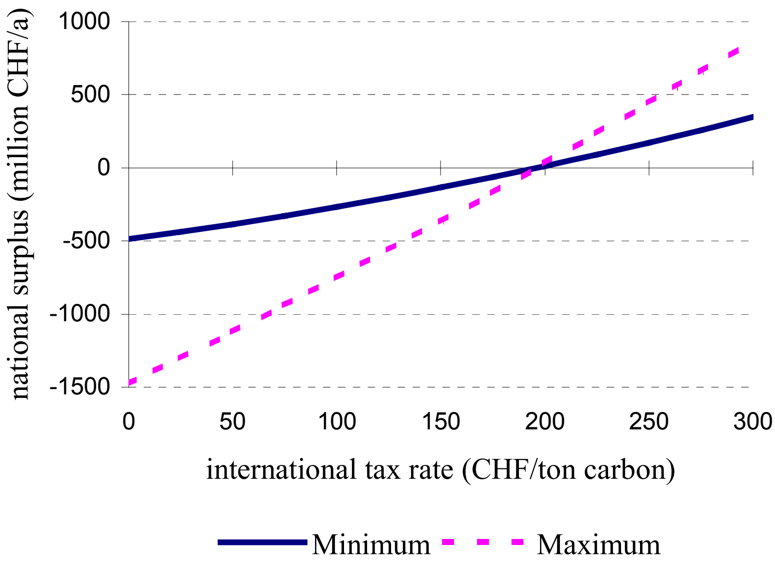

Figure 3 depicts the welfare consequences of an international carbon trade as a function of the global emission price. If emission rights were traded for free, Switzerland would incur a welfare loss between 0.5 and 1.5 milliard francs per year which corresponds to 0.125 to 0.375 percent of GDP. At a tax rate of 166 francs, no trade would occur and, thus, no welfare

[18] In the Kyoto protocol, Switzerland is committed to reduce greenhouse gas emissions by 8 percent only. However, for CO_2 emissions, the country unilaterally adopted a 10 percent goal.

changes would be caused. Only at the little plausible rates of more than 166 francs, Switzerland would offer emission rights which resulted in less local pollution and in a welfare increase.

The welfare loss in Switzerland due to carbon trade is accompanied by a benefit for the country that is selling emission rights. The size of the benefit is determined by the external effect in the selling country. According to theory, this benefit rises with population density and wealth, and it decreases with abatement activities.

4 Conclusion

This paper applies a simple model to analyze the welfare effects of international carbon trade when the burning of fossil fuels produces local externalities. Such a joint production of global carbon emissions and local pollution is inherent to fossil energy use. However, it is not considered in the literature on international carbon policy.

Due to persisting local externalities, international trade in carbon emission rights does not yield an efficient international allocation of globally fixed fossil energy. Without internalization of these local effects, trading regions equalize the private marginal product of energy. However, the social marginal product of energy is not equalized as long as the value of the local externality differs in the trading regions. The – negative – value of the externality rises with the relative scarcity of environmental quality as compared to the private good and with population density. As a result, the possible distortion arising from carbon trade increases with differences in private wealth and population density. To derive the result, only a few and rather safe assumptions must be met, i.e. constant returns to scale in the production of the private good, non-decreasing marginal damage of energy, and environmental quality being a normal good. If we presume, on the other hand, an increasing marginal damage of energy and a large income elasticity of environmental demand, then the externality in the rich region would be even bigger, leading to a larger possible distortion.

The situation is different when one of the trading regions internalizes its local external effects. In this case, international carbon trade equalizes the social marginal product of the internalizing region with the private marginal product of the non-internalizing countries. Now the possible distortion is determined by the externality in the latter region only. The poorer and the more sparsely populated this region is, the smaller the maximal possible distortion is.

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[19] Weyant and Hill (1999), p.xxxi.

It is sensible to argue that it is the rich region that rather internalizes the local effects. However, the case of Switzerland shows that, in spite of strict environmental laws, there remains a substantial externality when fossil fuels are used. With the assigned emission rights in the Kyoto protocol, it is to be expected that Switzerland buys emission rights. As a consequence, local environmental quality deteriorates relative to a situation without trading possibilities and an estimated welfare loss of around 0.25 percent of GDP is incurred. Despite partial internalization, Switzerland most probably loses. The country that sells emission rights to Switzerland, on the other hand, unequivocally benefits.

The theoretical analysis can show what the possible consequences of international carbon trade are. The actual outcome and welfare consequences, however, are crucially dependent on the initial assignment of emission rights as well as on the degree of internalization in the trading regions. The empirical illustration for Switzerland allows us to derive numerical results for the country itself but not for all trading regions. To derive quantitative results on a global level, such information needs to be collected internationally and applied in an global equilibrium model.

For the time being, we are left with the unpleasant knowledge that international carbon trade cannot guarantee a more efficient allocation of fossil energy as long as the burning of fossil fuels causes non-neglectable local externalities. This is particularly relevant for the buying countries. While the incidence of carbon trade is always at the benefit of selling countries, the buying countries might incur a substantial welfare loss.

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